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SUMMA SUMMARY

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The SUMMA (Small Unit Maintenance Manpower Analyses) Model is a microcomputer-based decision aid intended to portray the consequences of maintenance job redefinition. This job redefinition typically takes the form of job merger or job enlargement. The impetus for broadening the maintenance workforce in this way is to ensure adequate manpower support for dispersed, small-unit combat operations. The issues surrounding maintenance job definition have taken on new importance. Rivet Workforce and the Air Force IMPACTS program, for example, affirm the need for coherent and credible methods for weighing the risks and the benefits of maintenance job enlargement.

The SUMMA Model includes a task allocation algorithm which computes manpower requirements for given Air Force Specialty (AFS) alternatives in given deployment scenarios, and a personnel, training, and cost projection module. The SUMMA Model is tied to the Air Force Logistics Composite Model (LCOM) both as a source of maintenance task information and as a means of verifying the performance of altered job specialties.

The logic and data structure of the SUMMA Model are emphasized. Representative findings and potential uses of SUMMA for unified manpower, personnel, and training (MPT) analysis are also discussed.

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SUMMA SUMMARY

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SUMMARY

This paper describes the SUMMA (Small Unit Maintenance Manpower Analyses) Model. The SUMMA Model is a microcomputer-based decision aid intended to portray the consequences of maintenance job redefinition. This job redefinition typically takes the form of job merger or job enlargement. The impetus for broadening the maintenance workforce in this way is to ensure adequate manpower support for dispersed, small-unit combat operations. The issues surrounding maintenance job definition have taken on new importance. Rivet Workforce and the Air Force IMPACTS program, for example, affirm the need for coherent and credible methods for weighing the risks and the benefits of maintenance job enlargement.

The SUMMA Model includes a task allocation algorithm, which identifies new or revised Air Force Specialties (AFS), and a manpower, personnel, and training model (MPT), which projects the consequences of implementing given AFS definition strategies. The SUMMA Model is tied to the Air Force Logistics Composite Model (LCOM) both as a source of maintenance task information and as a means of verifying the performance value of altered job specialties.

The analytics and data structure of the SUMMA Model are emphasized. Potential uses of the SUMMA Model for unified manpower, personnel, and training (MPT) planning and analysis for new systems are also discussed. Follow-on development work includes validation of the SUMMA manpower estimator, refinements and expansion of the personnel and training impact analysis methods, and integration of the SUMMA Model with other MPT-oriented models and data bases.

PREFACE

The principal research effort was carried out under AFHRL Work Unit 1710-00-04 through a contract (F33615-84-C-0057) to Universal Energy Systems, Inc. (Dayton, Ohio) and Advanced Technology, Inc. (Reston, VA). The graphics in this paper were recreated by Brian Smith and editing help came from Matt Tracy. Thanks to both.

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I. INTRODUCTION

Objectives

SUMMA (Small Unit Maintenance Manpower Analyses) is an integrated modelling and analysis method, implemented as a microcomputer-based decision support tool, useful for examining alternative ways of organizing aircraft maintenance work into job specialties. The research has produced a working prototype, known as the SUMMA Model, that joins combat logistics analysis with manpower, personnel, and training (MPT) analysis in a unified approach to Air Force Specialty (AFS) job definition. The research objectives underlying the development of the SUMMA Model were to:

1. Identify, describe, and analyze maintenance work in ways useful for workload projection in different deployment scenarios.

2. Develop practical ways of allocating maintenance tasks to new or revised Air Force Specialties (AFSs), and of

3. Estimating unit performance and MPT impacts of these task allocation strategies.

4. Implement this integrated analysis procedure in a prototype decision support software environment.

This paper provides a summary of these research efforts and an overview of the current SUMMA Model implementation.

Background

Revising the task composition of maintenance AFSs has become an important objective in management of the maintenance workforce in recent years. Under the Rivet Workforce initiative, the entire array of maintenance AFSs has been studied for opportunities to merge or otherwise "restructure" jobs. The thought is that, in so doing, the maintenance workload to support peacetime flying training might be more equitably distributed among the various maintenance AFSs. Further, from a combat perspective, the added manpower needed for dispersed, small-unit deployments might be contained.

AFS job definition is important. Unit-level maintenance manpower requirements are driven in part by the number of separate specialties or AFSs required. In general, the more specialties, the more manpower. This staffing policy forces manpower utilization for some work centers to be low. But if the number of specialties were reduced -- through job enlargement, job merger, task transfers, or other means -- then unit manpower needs would decrease and average utilization would increase. In short, there is a trade-off between manpower policy, which governs how many people are needed to support a mission, and personnel policy, which governs how people's jobs are defined, and, hence, how they are trained and utilized. These MPT trade-offs are illustrated in a SUMMA report by Moore, Wilson, Seman, Eckstrand, Lamb, Lindeman, & Boyle (1987).

These trade-offs become especially noticeable and important if wartime basing plans call for small-unit, dispersed operations. In this case, computer simulations show, manpower requirements escalate very sharply under current AFS definition policy. But if the AFSs were

consolidated -- in effect, making people more broadly trained -- then manpower would not become such a limiting factor, at least not for small-unit deployments. This leveraging effect of a more versatile workforce became the principal impetus for the Rivet Workforce initiative (Boyle, Goralski, and Meyer, 1985).

Reorganizing maintenance jobs to increase combat capability is now an accepted Air Force objective. This objective has heightened the importance of advanced modelling and analysis tools for use as decision support aids. MPT trade-offs inherent in maintenance AFS revision are important ongoing issues. And since new Air Force policy directs greater attention to manpower, personnel, and training (MPT) factors in the design and acquisition of new systems, new analysis methods applicable to that environment will be especially valuable. The SUMMA Model, adapted and expanded for this purpose, will prove useful here as well.

II. SUMMA ANALYTICS

SUMMA analytic functions are organized around the problem of defining and evaluating alternative task-to-AFS allocations. As shown in Figure 1, these allocations are always tied to specific basing patterns and to projected combat maintenance task requirements. The analytic objective is to find improved task-to-AFS allocations. By improved, we mean that maintenance manpower will be minimized without sacrificing combat performance. We also mean that MPT costs of AFS job enlargement or merger will be balanced or traded-off against these performance requirements. This is shown as a six-step evaluation process that can be used iteratively to locate improved task-to-AFS allocations.

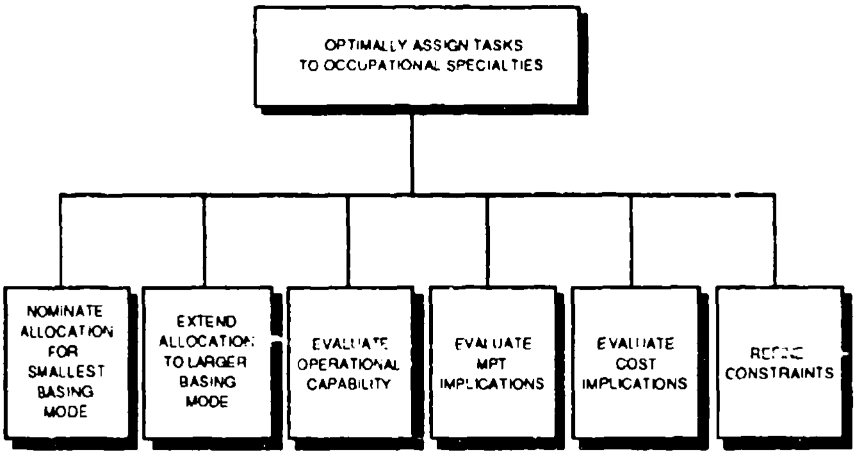

Figure 1. SUMMA Analytic Functions

The SUMMA Model joins three analysis processes in a single software application to allow a unified evaluation of alternative AFS strategies. As shown in Figure 2, these are the Logistics Composite Model (LCOM), a Task Allocation Optimization Model (TAM), and an MPT and Cost Model. This three-way integration, implemented in a fourth-generation database language called Revelation, creates a flexible and efficient analysis environment. The substance of each of these processes is briefly described below.

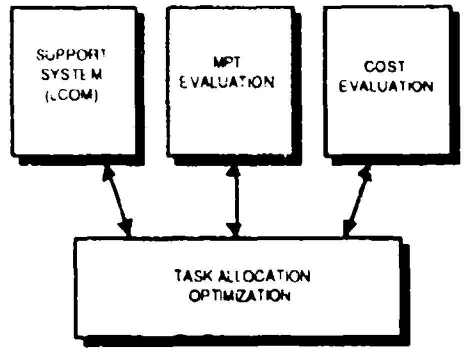

Figure 2. SUMMA Analysis Integration

Logistics Composite Model (LCOM)

The SUMMA Model is tied to this accepted and well established simulation approach for determining maintenance manpower requirements in two ways. First, LCOM data sets are used for maintenance task identification and description. All MPT requirements projected by SUMMA analytics are traceable to these LCOM data. Second, software utilities port LCOM data in and out of the SUMMA application environment. This allows LCOM simulation to be used in tandem with the SUMMA analysis process to verify the operational performance capability of new AFSs defined or evaluated by the SUMMA Model. This capability is estimated by sortie rates attained using new task-to-AFS allocations mapped into revised LCOM data sets. From an LCOM perspective, the SUMMA Model could be viewed as a logical extension of the existing process into MPT resource trade-off analysis.

Figure 3 and Figure 4 show the data structure of the LCOM data base, which is also called the LCOM "Forms", and the LCOM data required by the SUMMA Model, respectively. Nearly all maintenance tasks described in LCOM use the "action taken/work unit code" format. For example, T-74AB0 means troubleshoot the radar low power radio frequency unit. LCOM data bases also show the AFS currently assigned the task (e.g., 326X6 = radar technician), the expected task performance time, and task crew size.

Task Allocation Model (TAM)

The TAM is the core of the SUMMA Model. Using task information from the LCOM data base and task-by-task AFS substitution information obtained from a special-purpose task analysis, the TAM derives improved task-to-AFS allocations. As noted, improved means that a given maintenance workload in a given scenario is allocated to a reduced number of specialties. The task inventory of each resulting AFS is apt to be larger than before, but manpower for each AFS, and for the unit as a whole, will be lower.

The TAM locates the best task-to-AFS allocation strategies within a constraint set framed by a target aircraft sortie rate and the average allowable time for maintenance between sorties. The general logic implemented in the TAM is that task reassignment to substitute or alternate AFSs may be beneficial even if these AFSs take more time to perform the work than the primary AFS takes. From a TAM perspective, total maintenance time consists of the delay time awaiting a maintenance worker plus active repair time once the worker has arrived. The TAM will substitute (or reallocate) a task to a different AFS even if it takes that AFS longer to perform the work than the primary AFS if overall maintenance time in doing so is reduced. This would happen if maintenance delay time is

AIR FORCE FORM	FORM TYPE	FORM NAME	PURPOSE
2710	10	Performance Summary Report (PSR)	Defines the Main Module PSR reporting structure
2711	11	Task Network	Defines task networks
2712	12	Task Definitions	Defines task parameters
2713	13	Resource Definitions	Defines all resources and clocks
2714	14	Failure Clock Decrements	Defines task/clock relationships.
2715	15	Distributions	Defines empirical distributions
2716	16	Shift Change Policies	Defines authorizations by shift
2717	17	Mission/Activity Entry Points	Defines resources entering the network and the required configurations
2718	18	Priority Specifications	Defines priority systems parameters
2720	20	Sortie Generation Data	Defines mission and activity parameters
2721	21	Search Patterns	Defines external and internal configuration search sequence
2722	22	Internal Equipment Authorizations/Changes	Defines internal equipment, their authorizations, and trigger node effects
2723	23	Internal Equipment Group	Defines internal equipment groupings by aircraft
2724	24	Attribute Definitions	Defines the aircraft and system owned attributes

Figure 3. LCOM Forms

shortened more than active repair time is lengthened by using alternate AFSs. The TAM uses a Lagrangian non-linear mathematical optimization algorithm to define the lowest manpower for each AFS. This is given mathematically as:

$$X_j = \frac{\left(\frac{(\alpha - 1)}{2}\right) \sum_{j=1}^{m} \sqrt{D_j}}{A - \sum_{j=1}^{m} C_j} \sqrt{D_j}$$

where α = number of aircraft in the analysis
X_j = optimal manpower required by AFS
= number of aircraft to be maintained
C_j = total expected clock hours of work by AFS
D_j = total expected manhours of work by AFS
(D is C adjusted for task crew size)
A = average inter-sortie maintenance time available

This expression makes manpower proportional to the number of aircraft in the analysis. That is, as the number of aircraft increases, so does the manpower requirement. Manpower in a given AFS increases in proportion to the total work required of all AFSs through the sum of the square roots of the crew hours. The denominator represents the "slack" time between the allowable work time, A, and the total expected hours of work required on the aircraft. Total manpower is then the sum of the optimal manpower required for each AFS for the task allocation specified. The SUMMA paper by Wilson, Faucheux, Gray, and Wilson (1987) contains a full mathematical derivation of this TAM porcedure. Restructuring AFSs using the TAM is a two-stage process.

SUMMA Model	Data Provided by				Data Required by	
Required Data	Form 11's	Form 12's	Form 13's	Analyst Input	Tree File	Task File
Prior Node	●				○	
Task Name	●	●			○	○
Next Node	●				○	
Task Probability	●				○	○
Mean Task time		●				○
AFS(s)		●				○
Crew Size(s)		●				○
Clock Names	●		●		○	
Mean Sorties Between Failures			●		○	
Activity Entry Points				●	○	
Activity Probability				●	○	
Mission Entry Points				●	○	
Mission Mix (Probability)				●	○	
First Line of Task Network				●	○	

Figure 4. SUMMA/LCOM Data Correspondence

The first stage minimization process is a simple combinatorial analysis of potential substitutions of one AFS for another. For example, if there were 14 "on-equipment" AFSs and every AFS could perform every task of every other AFS, then there would be 16,383 possible combinations of AFSs that could be allocated tasks. These theoretical combinations would include the current allocation to 14 AFSs down to 14 possible allocations of all tasks to a single AFS. The TAM selects the combination of AFSs that requires minimum total manpower. It then evaluates any constraints imposed on the task allocation process. The user may enter blocks at the task or AFS level to prevent unwanted AFS or task combinations or to preserve a preferred task-to AFS allocation. If the constraints are not satisfied, the TAM selects the next best combination of AFSs, evaluates the constraints again, and continues iterating in this fashion until a solution which satisfies all constraints is found.

In the second stage, another TAM algorithm locates task-by-task substitutions which will lead to further minimization of the total manpower requirement. This second-stage algorithm computes a delta factor for each potential task/AFS combination. A negative delta for a specific AFS "swap" on a specific task indicates that a decrease in total manpower will result from making the change. In that case, the TAM will make the change and then recompute new deltas for each possible task/AFS substitution. The TAM then iterates until it has found the minimum manpower solution.

At this point, the TAM stops and provides summary data on three task-to-AFS allocations: (a) the beginning or baseline allocation; (b) the minimum manpower allocation; and (c) the lowest manpower allocation that satisfies all constraints. Manpower for each task-to-AFS allocation is also computed. Aggregated manpower requirements, summing over all bases in the analysis, are

also computed and displayed. The analysis may include one base, several bases, or even the entire deployed fleet of combat aircraft. However, the SUMMA Model is limited to a single aircraft type.

Task performance time data for alternate or substitute AFSs used by the SUMMA TAM are generated from a task analysis using maintenance subject-matter experts. The current process permits up to five alternate AFSs to be identified for each task in the LCOM data base. These AFSs, and their average estimated task performance times, are the principal data used by the TAM in identifying new or revised AFSs.

The TAM process described above is applied at present only to "on-equipment" or flightline maintenance work. For "off-equipment" or shop work a straightforward manpower utilization model is used. The amount of work required is merely the sum of the expected work on each "off equipment" task over the time period involved. This is each task's probability of occurring within the time period specified multiplied by the time to perform the task. The number of maintenance people required is the total manhours of work required divided by the manhours available per person. (This is further adjusted for less than 100 percent direct manpower utilization.) It might be noted that, as presently implemented, the TAM seeks to minimize only total field manpower when composing these AFSs, and that its task "swapping" rules are based only on task performance times of potential task substitutes. Optimization using other relevant criteria, such as time to become trained, is not handled directly within the TAM. It is possible to give effect to any number of MPT-oriented constraints within the current TAM process through the AFS- and task-level blocking features incorporated in the SUMMA Model software. But a serious limiting factor in this regard is the lack of empirical data for making informed judgments regarding personnel and training variables and especially about their interactions.

MPT and Cost Model

The SUMMA MPT and Cost Model contains a number of analysis procedures for comparing one task allocation strategy with another and for estimating the overall impact of implementing a given AFS strategy. Many of these procedures are based on supplemental task characteristic data gathered from maintenance job incumbents during the research. In addition to the task characteristics already described (alternate AFSs, task times, crew sizes, etc.), these include, for each task, the average (7-point scale) rated:

- Level of difficulty
- Number of repetitions to reach proficiency
- Probability of successful completion
- Electronics knowledge/ability
- Mechanical knowledge/ability
- Fluids and gases knowledge/ability
- Computer/microprocessor knowledge/ability
- Aircraft structures knowledge
- Adherence to procedures
- Number of procedural steps
- Decision making/problem solving
- Reading/using complex instructions

Formal Training

The SUMMA model for formal training assumes that current training times for each AFS are related to the time required to train the specific tasks assigned to each AFS. It also assumes that training time is (or should be) a function of certain task characteristics. Given these assumptions,

the core idea of the SUMMA training model is that the total current training time can be broken down into some proportional amount of time allocated to each task, based on one or more task characteristics assumed to be predictive of training length.

The SUMMA training model computes each task's share of the current training time as the ratio between a selected task characteristic value for the task and the total of that characteristic's value for all tasks included in the training course. For example, suppose "number of repetitions" is chosen as the task characteristic most predictive of training time. If a given task has an average rating of four repetitions, and the sum of all repetitions ratings over all tasks in the AFS is 100, then this task accounts for 4/100 (or 4 %) of the total repetitions needed to become proficient in that AFS. Then, if the total training time for this AFS is 500 hours, then 4% X 500 hours or 20 hours would be the estimated time allocated to train this task.

The training analysis can be extended to account for fixed or non-task-related training requirements. The time for general "skills and knowledge" training is subtracted from the total course time before the remaining time is allocated to the individual tasks. For example, if the fixed time to cover non-task-specific training were 100 hours, then 500 - 100 = 400 hours remain to be allocated among the specific tasks to be trained. For the example above which represented 4% of the total number of repetitions needed to learn the task, training time is calculated as 4% X 400 hours = 16 hours of training.

The SUMMA training analysis can also be easily extended through input screen menus to allow the use of more than one task characteristic simultaneously. In this case, the analyst must enter weighting factors for each characteristic to ensure that the total characteristic weights sum to one. Table 1 shows how the data would be organized for this type of analysis. In this example, four task characteristics are included. As before, the ratio of the task characteristic value for each individual task to the total value for that characteristic is computed. These values are then multiplied by an analyst-defined weighting factor. Finally, the products are summed. Using the data in Table 1, this arithmetic would yield a value of .0144. Then, using the same 400 hours from the previous example, the training time for the specific task is 400 X .0144 = 5.76 hours.

Table 1. Training Model Using Four Task Characteristics

	Task Characteristic (TC)			
	Level of Difficulty	Number of Repetitions	Electronics Knowledge	Mechanical Knowledge
Value of TC for Task X	5	4	5	3
Total Value of TC for All Tasks in AFS	325	278	312	378
Proportion Task/Total	0154	.0144	.0160	.0079
TC Weight	.5	.3	.1	.1

The training course length for a new AFS derived by the TAM is then simply the sum of the fixed training time for the new AFS and the sum of the individual task training times for the new AFS. The SUMMA training model is intended to be used flexibly. Any number of task characteristics and weighting schemes can be used, and separate models can be built for in-residence technical school and field training detachment (FTD) settings. However, the SUMMA

approach for formal training is also very limited in scope. It does not attempt to do Instructional System Development (ISD) analyses nor does it handle changes in training technology or training policy. A host of models and analysis aids for these sorts of training issues have been developed, and many seem easily adaptable to the SUMMA analysis process.

Manpower Requirement for Training

The total manpower for any AFS includes both the requirement for people in field units and the requirement for people to be in training so that the people in the field can eventually be replaced. This latter portion of the manpower pool is usually called the training pipleline requirement, or TPR. Accordingly, the SUMMA manpower model computes both world-wide manpower requirements for field duty for the weapon system under study as well as manpower requirements, including recruit requirements, needed to fill the training pipeline. The algorithm used for the training pipeline manpower computation takes into account the length of the training course, computed as discussed above, enlistment term length, and training "washout" rates. The trade-offs in field vs. training manpower costs as the task composition of AFSs expands are readily estimated in this way.

On-the-Job Training Impact

On-the-job training (OJT) involves guided practice in performing job tasks in the actual work setting. Maintenance people become task certified and qualify for "skill-level" upgrade and promotion by completing the program of OJT prescribed for them. AFS job enlargement implies that a larger repertoire of job tasks will have to be mastered, and hence, that maintenance people could remain in OJT status longer, possibly much longer, than they had previously. We have developed indicators that show whether OJT "saturation" created by expanded AFSs will slow down upgrade/promotion rates.

An estimate of the time to qualify in all tasks in an AFS is created from measures of (a) the frequency with which a task occurs, which is influenced by the reliability of the equipment to be maintained and the equipment utilization (sortie) rate; (b) the number of repetitions required to reach proficiency, and (c) the number of tasks in the AFS. A "minimum time to qualify" metric is derived from combining these variables. This is a theoretical, idealized metric in that it assumes a perfect assignment of tasks; that is, the tasks occur at just the right time and in the right sequence to allow just the right person to become experienced in doing the task. Even so, the metric is useful in comparing one AFS restructure option with another. Similarly, the analyst may divide the "minimum time to qualify" metric by some standard "time to upgrade" to see the potential impact of expanded AFS task responsibility on first-term promotions. For example, suppose Air Force policy afforded first-term airmen a chance for promotion at 24 months in service if all OJT were completed. Further, suppose the computed initial training plus OJT time to qualify on all tasks was 26 months. This would suggest that airmen will not be able to meet minimum qualification standards for promotion in the first enlistment term. The Air Force would experience grade imbalances and very likely lowered morale as a result.

Aptitude Requirements

The SUMMA Model computes an estimate of task-based aptitude requirements for stating AFS recruiting and selection standards. The method approximates the so-called ATDPUTS (Average Task Difficulty Per Unit Time Spent) aptitude metric. ATDPUTS is the preferred Air Force method for determining AFS aptitude requirements based on job difficulty. This metric grew out of Air Force research which has shown that task/job difficulty is inseparable from aptitude when difficulty is measured in terms of the time it takes to learn to do a job proficiently. ATDPUTS is

computed (within two separate aptitude areas - electronic and mechanical, in SUMMA's case) by summing, over all tasks in an AFS, the cross-products of rated task difficulty and percent time spent on each task. We approximate this ATDPUTS metric using the SUMMA task characteristic variable of number of repetitions (a difficulty proxy) and a weighted measure combining expected task frequency and performance time, a time spent proxy derived from LCOM.

A more focused measure of mechanical and electronic aptitude requirements for specific jobs can be obtained using this weighted task difficulty approach by selecting tasks that have relatively high ratings by maintenance subject matter experts for mechanical and electronic abilities. In addition, a procedure for converting aptitude measures into rough ASVAB (Armed Services Vocational Aptitude Battery) percentile scores equivalents through Z-score transformations for the mechanical and electronic aptitude areas is embedded in the SUMMA Model software. This procedure assumes that the nominal ASVAB electronic and mechanical cutoff scores for selection into an AFS can be regarded as the means of normally distributed aptitude scores. This assumption may be invalid if actual ASVAB minimums are set using criteria other than, or in addition to measured job difficulty.

Task Saturation

An experimental metric for task learning saturation is included in the SUMMA Model. Although there is nothing inside the SUMMA Model to suggest practical limits on the number of tasks that can be assigned to one person, we know such limits must exist. Theoretically, it could be argued that, given enough training and time, one person, or one AFS, could learn to do all or almost all required maintenance tasks on a modern Air Force fighter. But in the real world, we know that the prospects for job enlargement will be limited by many factors. The difficulty is that we don't really know where those limits are.

Absent direct empirical evidence, perhaps the best one can do is to propose ad-hoc indicators that can inform subjective judgment. In SUMMA, these indicators are three: the number of tasks in an AFS, the difficulty of those tasks, and the mix of aptitude requirements needed to learn and perform them. We obtain "before and after" measures of these three and display them, separately and combined, as a task saturation vector.

Job Performance Aid/Training Trade-off

A second experimental procedure aimed at mitigating formal training costs for expanded AFSs has been included in the SUMMA Model. This is called the JPA/Training Trade-off Model. The analyst can flag each maintenance task, or bundles of maintenance tasks, as best supportable through a job performance aid, which can be defined as a proceduralized, "user friendly" task instruction, or through formal technical training, or through a combination of the two. The idea is to take account of the finding that some maintenance work, particularly non-troubleshooting jobs, does not require formalized technical school training, but merely supervised on-the-job experience supported by step-by-step job guides. To the extent that maintenance tasks can be reliably and validly categorized on the JPA vs. training dimension, the formal training requirement and associated costs attributable to expanded maintenance jobs might be avoided or reduced.

Further, anticipating the appearance of advanced technology JPAs such as the Integrated Maintenance Information System (IMIS), one might forecast lowered task performance times, fewer maintenance errors, and greater OJT "capacity." In a SUMMA analysis context, these improvements would have leveraging effects on the task allocation process by allowing much freer task substitution, and hence, greater AFS consolidation, without increasing MPT costs.

A probe study using a panel of JPA technology experts was performed. These people were asked to judge, for a sample of SUMMA tasks and SUMMA task characteristic profiles, whether JPA, training, neither, or both approaches would be preferable. The objective was to identify the best discriminators from among the SUMMA task characteristics. The results were equivocal. Most judges favored the combined JPA plus training approach. It is not known whether the task characteristics measured by the SUMMA research are not good discriminators for this purpose, whether the sample of maintenance task was not well chosen, or whether the findings present an accurate picture of ambiguity. In any case, the JPA/Training Trade-off Model is in need of further research. At the moment, it is useful principally for data conditioning in "what if" excursions using the TAM.

Assignment Progression

A personnel "flow" algorithm is incorporated in the SUMMA Model. This is used to model the impact, if any, of the revised AFS policy on assignment. For an enlisted person in any given assignment, there are three potential new assignments: (a) overseas long tours of 36 months; overseas short tours of 12 months; and CONUS tours. The key question is whether changing the AFS structure introduces hardships in CONUS/Overseas rotation patterns.

The assignment algorithm requires for each AFS the number of overseas long tour, overseas short tour, and CONUS billets. The analyst provides the number of bases, their geographic locations, and tour length designation as part of the scenario definition prior to running the TAM. The other information required is the probability of transition from each state to each other state in a given period. This approach, which is based on a finite Markov transition probability matrix, gives useful information about the assignment difficulty that may be introduced by CONUS/Overseas imbalances.

MPT Costs

The SUMMA Model computes annual costs mainly from the standpoint of manpower resources. All costs are based on standard Air Force cost and planning factors. SUMMA uses a very simple cost accounting approach. The manpower categories accounted for are total field maintenance personnel, basic training, resident school, and field training detachment personnel, and personnel in transit between duty stations. These five categories are tracked by AFS. The field manpower requirement is partitioned into 20 year-of-service (YOS) groups according to the typical pyramid rank/paygrade structure, and manpower costs by AFS are computed using standard Air Force data on pay and allowances. The cost for the training pipeline is computed using standard Pipeline Management System (PMS) data. The average cost per move (permanent change of station) is multiplied by the expected number of moves for the AFS restructure option and deployment pattern under study. Finally, recruiting costs are simply the number of recruits multiplied by the cost per recruit. All these costs are displayed for each task-to-AFS allocation policy, so that direct cost comparisons of AFS alternatives can easily be made.

SUMMA Data Base Structure

All the above SUMMA analytics are housed in a data base applications package called Revelation (Cosmos, Inc. 1985). The software includes data entry utilities, user interface, and programs for LCOM interaction. Only the LCOM portion of the SUMMA analytic process requires the user to exit the microcomputer environment. LCOM software exists for use on several different mainframes and, increasingly, on minicomputers. We are using an ASD version of

LCOM on a VAX 11/785 minicomputer at present. Everything else for the SUMMA Model is housed within a standard 20-megabyte Zenith 248 microcomputer setup.

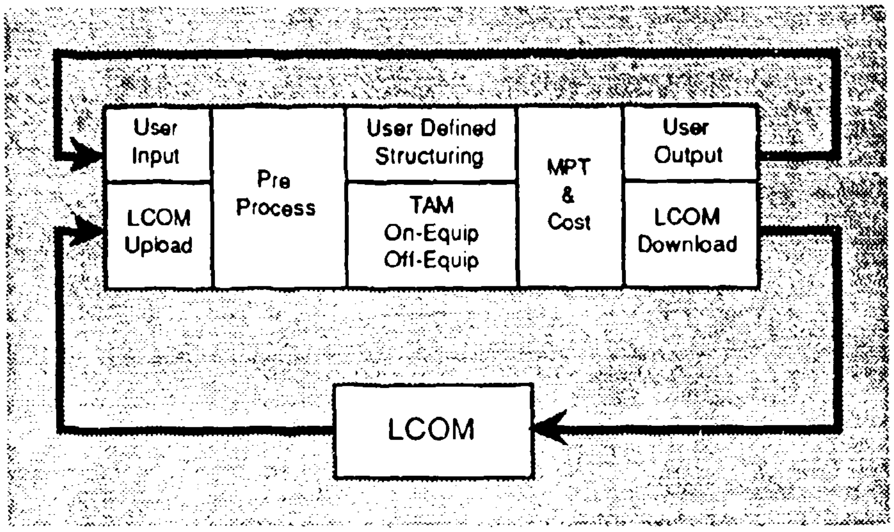

Figure 5. SUMMA Analysis Sequence

Using the SUMMA Model implies an analytic sequence as shown in Figure 5. First, pertinent LCOM task data are uploaded to the SUMMA data base. A data preprocessing phase then assembles the LCOM and SUMMA task characteristic data into the format needed for the TAM algorithm. Details of the basing and mission requirements are also entered through menu-driven screens. The analyst also enters any task or AFS blocking instructions for the TAM analysis. The TAM is run separately for flightline and shop task allocation. The resulting task-to-AFS allocations are passed to the MPT and Cost Model for further analysis. When the analyst has obtained a satisfactory solution, a revised LCOM Form 12, which contains a list of maintenance tasks and their associated AFSs, is written for incorporation in an LCOM simulation. This simulation will be focused on a single airbase and will use a scenario identical to the one used in the SUMMA TAM. The principal objective in using the revised task-to-AFS allocations in LCOM is to verify that the required sortie rate is indeed obtained with the TAM-revised AFSs manned at specified levels.

An overview of the current SUMMA data base file is shown in Figure 6. The content of each data base file is shown in Figure 7. (The Task File does not show several of the task characteristics listed on page seven.) Data entry is through the computer screen or through upload from floppy or hard disk files. The logic of the SUMMA/LCOM interface is shown in Figure 8 in low detail and in Figure 9 in higher detail.

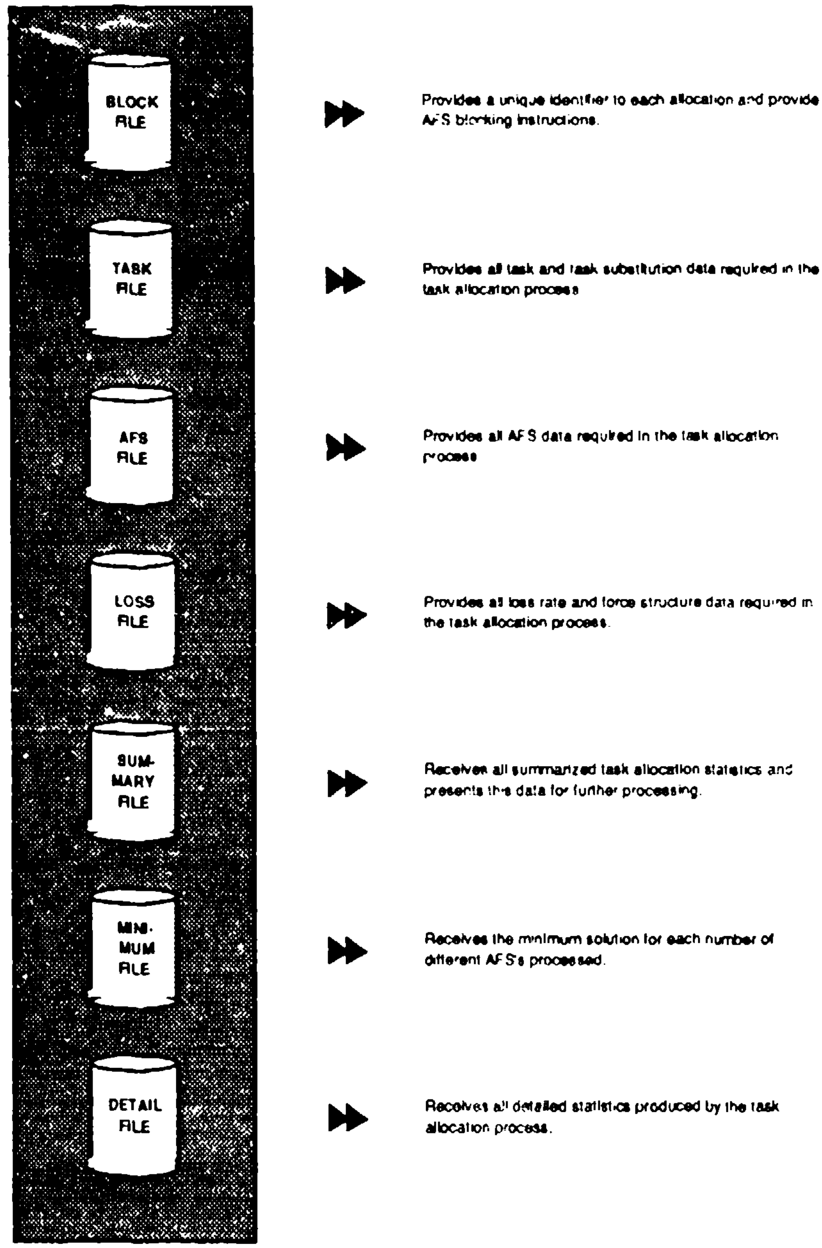

Figure 6. SUMMA Data Base Overview

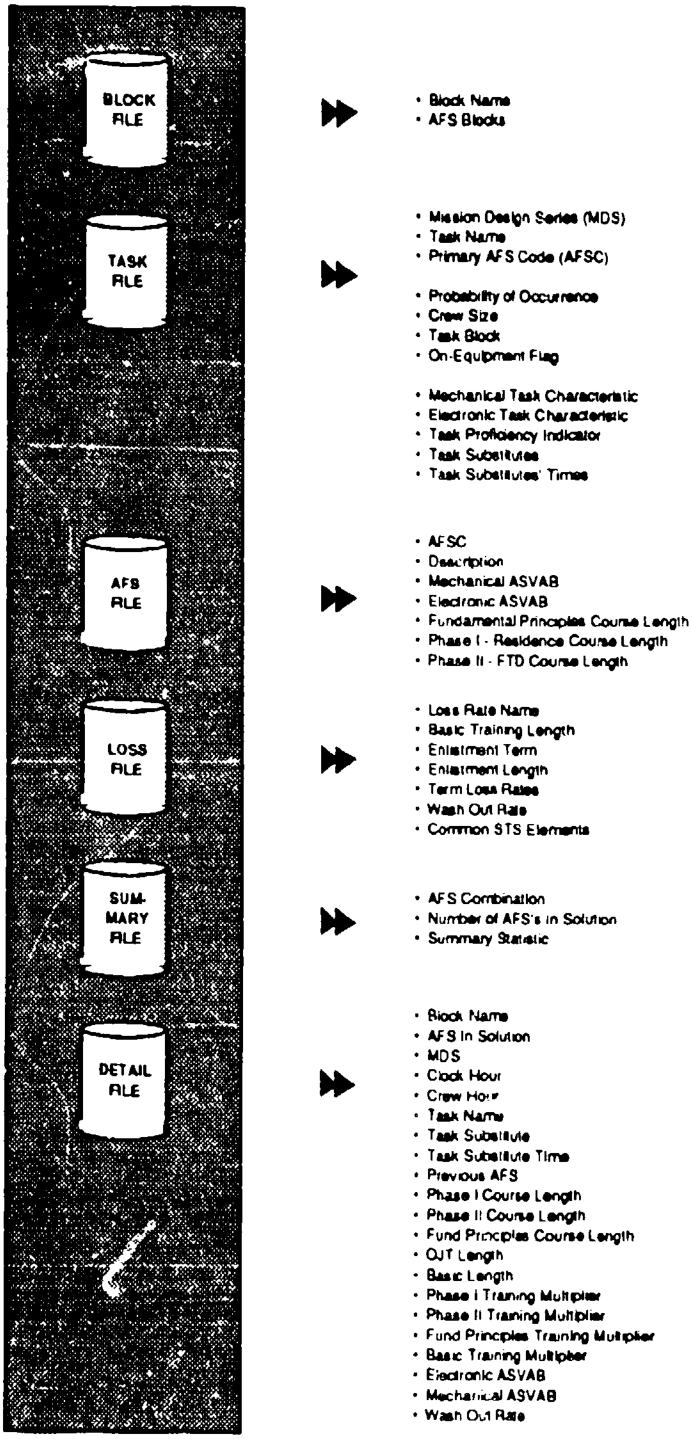

Figure 7. SUMMA Data Base Detail

III. DISCUSSION

Applications of the SUMMA Model

The SUMMA Model was developed using the F-16 as the source of maintenance task requirements. Five F-16 locations were visited during the research and several hundred maintenance technicians participated in face-to-face task analysis interviews. This effort is described in detail in a paper by Lamb, Eckstrand, Seman, and Lindeman (1987). The prototype SUMMA Model was tested using this F-16 data base in a series of sample applications. The results, reported in a paper by Boyle (1989), confirmed the overall utility of the SUMMA Model. The utility of the SUMMA Model was separately confirmed using an LCOM data base developed specifically for the purpose in a study of AFS options for the Air Force Advanced Tactical Fighter program. Results of that study are also reported in Boyle (1989).

However, as pointed out in an unpublished review by Miller, the accuracy and sensitivity of the SUMMA manpower estimation procedure is not yet fully verified. There are indications that the TAM, which is an analytic (i.e., deterministic) model, may understate manpower requirements and may behave in inconsistent ways when different sortie rates or, conversely, different maintenance workload factors are applied. One cannot know without further testing of the TAM using more rigorous and systematic procedures than we have used to date. This work has started.

SUMMA Model Transition

Meanwhile, portions of the SUMMA Model have already been identified for immediate use by the Manpower, Personnel, and Training Directorate at Aeronautical Systems Division (ASD/ALH) to support personnel and training analysis for new systems. Fuller transition of the complete analysis package awaits verification (and adjustment, if needed) of the SUMMA manpower calculation procedure). Other avenues of transition are discussed in detail in Boyle (1989).

Extending the SUMMA Model

The SUMMA Model is limited to analysis of a single deployed weapon. To be sure, the entire weapon fleet and dozens of bases can be included in a SUMMA analysis, but only that weapon, no others. Since the AFS definition issue goes far beyond just one weapon system, and since this issue is at the heart of MPT force management, the solutions proposed or evaluated in the SUMMA Model are by no means complete ones. Clearly, some way of linking the micro-MPT issues dealt with in the SUMMA Model with the macro-MPT issues Air Force-wide is needed. For example, if we expand AFSs on one weapon system, do we need to "close loop" their assignments to that weapon system to protect the job experience gained? Or can we allow people to "free flow" from one weapon system to the other? This and a host of other MPT force management issues will arise in any serious discussion of AFS revision. Indeed, the "closed loop/free flow" issue has been a dominating one in Rivet Workforce. Ways to frame this issue and others related to it at the macro-MPT analysis level have been proposed in a recent paper by Akman and Boyle (forthcoming). The hope is that least some of these force-wide issues will be tractable enough to be included in micro-MPT SUMMA analytics in the near future.

Also in the near future, a more fully instrumented and validated JPA/training trade-off analysis capability for use within the SUMMA Model will be developed. In addition, the integration of SUMMA analytics with the AFHRL Training Decisions System (TDS) is being explored. If successful, this integration would permit economic trade-off analysis of different training strategies

for newly created or revised maintenance AFSs to be performed. This cost-effectiveness analysis of training alternatives is badly needed.

Finally, the TAM logic and data base are being changed to allow predefined AFSs to be evaluated directly by the SUMMA Model. The TAM was designed to operate in a scenario where AFS substitution, which is an analogue for AFS merger, implies greater task performance time. In practice, this may not always be a valid assumption. And, at any rate, when the AFS solution is known beforehand, the practical problem is to evaluate MPT impacts of a preferred AFS pattern versus another proposed solution. For these reasons, the TAM will be revised to operate without task time penalties for alternate AFSs.

MPT Analysis For Acquisition

The SUMMA Model has been shown to be particularly useful for MPT trade-off analysis of alternative maintenance AFS strategies in weapon design and acquisition. The SUMMA Model might be compared to existing MPT analysis procedures such as Hardman and kindred tools in this regard. The value added by the SUMMA Model in this context is in focusing on AFS definition as the critical factor in determining manpower, personnel, and training requirements for system support. The SUMMA Model's tie-in with LCOM, which has been used effectively itself for early manpower forecasting, lends credibility to the results. But it also helps to make MPT analysis more coherent and efficient. One may hope that as IMPACTS draws greater attention to MPT supportability issues in weapon design, more attention will inevitably focus on perfecting the SUMMA Model to those ends.

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APPENDIX

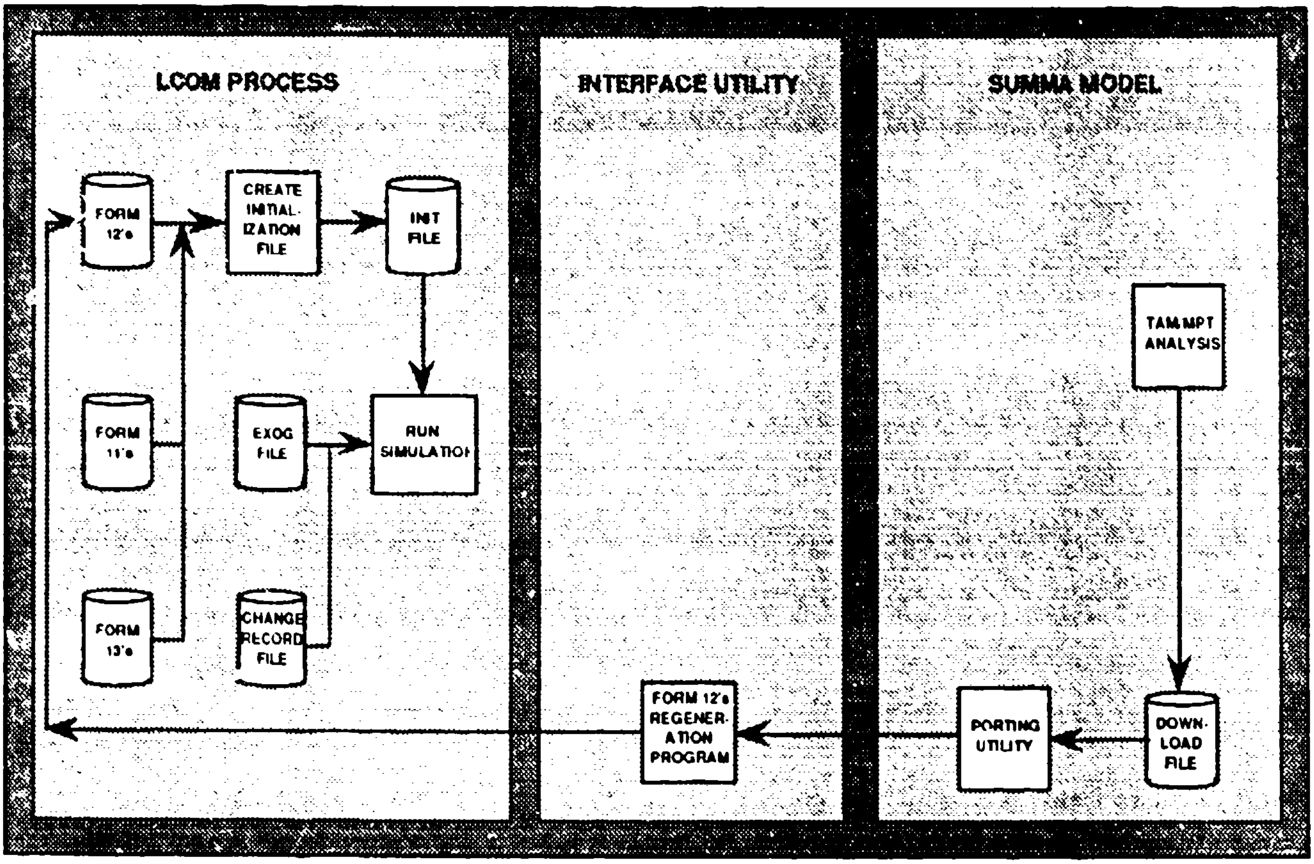

Figure 8. SUMMA/LCOM Interface Overview

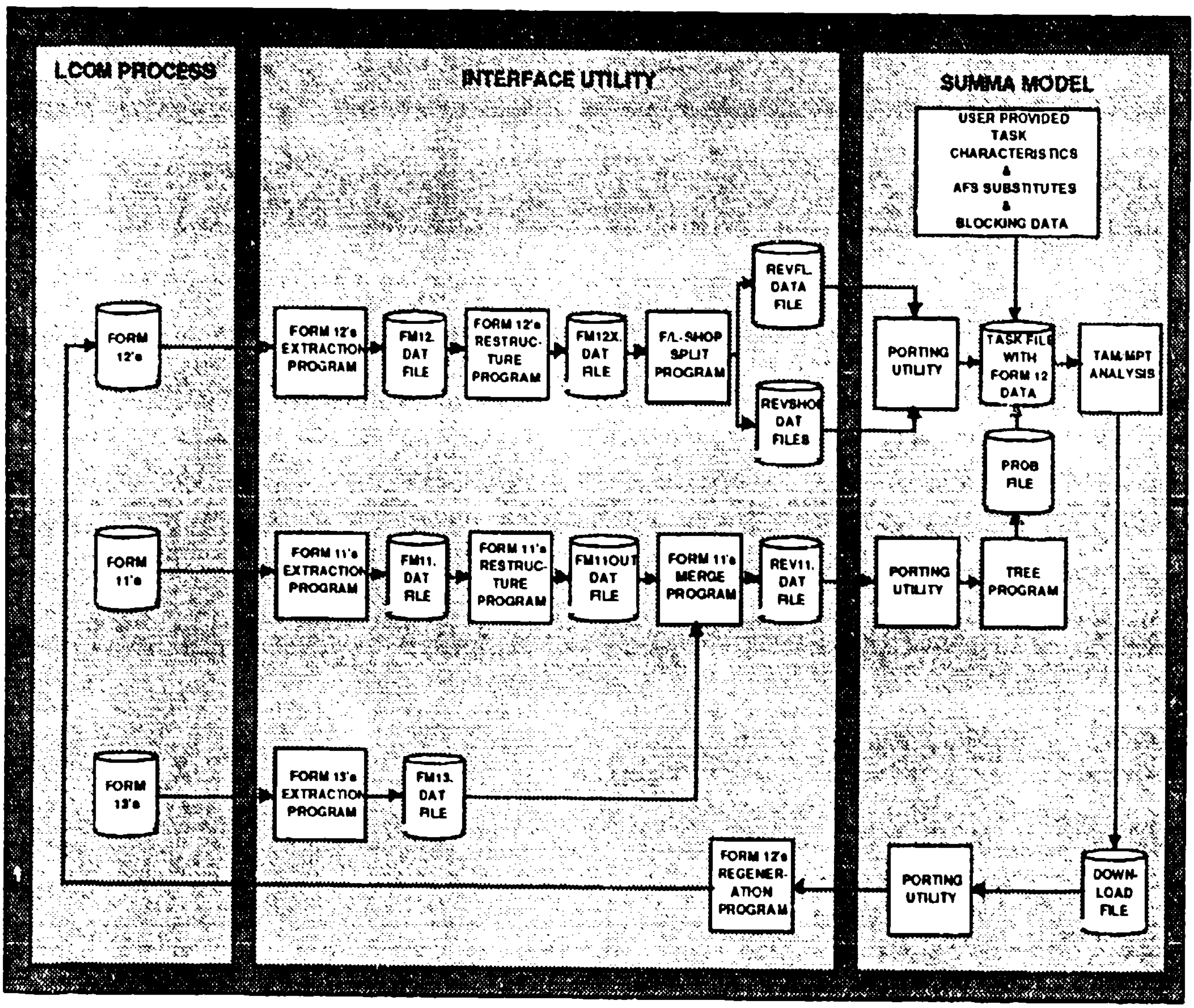

Figure 9. SUMMA/LCOM Interface Detail